

Results from the commissioning of the ALICE Inner Tracking System with cosmics

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Abstract

The Inner Tracking System (ITS) is the detector of the ALICE central barrel located closest to the beam axis and it is therefore a key detector for tracking and vertexing performance. Here, the main results from the ITS commissioning with atmospheric muons in 2008 are presented, focusing in particular on the detector operation and calibration and on the methods developed for the alignment of the ITS detectors using reconstructed tracks.

1. Introduction

The Inner Tracking System (ITS) of the ALICE experiment [1] consists of six cylindrical layers of silicon detectors located at radial distances of $\approx 3.9, 7.6, 15, 24, 38$ and 43 cm from the beam axis and covering the pseudo-rapidity range $|\eta| < 0.9$. The two innermost layers are equipped with 240 pixel detectors (SPD), the two intermediate layers are made of 260 drift detectors (SDD), while 1698 strip detectors (SSD) are mounted on the two outermost layers. The number, position and segmentation of the layers, as well as the detector technologies, have been designed according to the requirements of efficient track finding in the high multiplicity environment predicted for central Pb–Pb collisions at LHC, high resolution on track impact parameter and minimization of material budget (multiple scattering). Hence, the ITS allows to improve the momentum and angle resolution for tracks reconstructed in the TPC, to recover particles that are missed by the TPC (due to either dead regions or low- p_t cut-off), to reconstruct the interaction vertex with a resolution better than $100\text{ }\mu\text{m}$ and to identify the secondary vertices from the decay of hyperons and heavy flavoured hadrons [2]. By associating pairs of reconstructed points in the two SPD layers, it is possible to build “tracklets” that are used to reconstruct the interaction vertex position (which provides a starting point for the Kalman filter in the tracking phase), to tag pileup events on the basis of multiple vertices and to measure the charged particle multiplicity in the wider pseudorapidity range ($|\eta| < 2$) covered by the SPD layers. The four layers equipped with SDD and SSD provide also particle identification capability via dE/dx measurement. This feature allows to use the ITS also as a standalone spectrometer, able to track and identify particles down to momenta below $200\text{ MeV}/c$. Furthermore, the SPD FastOR digital pulses provide a unique prompt trigger signal.

2. ITS installation and commissioning

The installation of the ITS detectors and the beam pipe in the ALICE cavern was completed in June 2007. A first commissioning run was performed in December 2007 to test the acquisition and the calibration strategy on a fraction of modules for which power supplies and cooling

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were available. A larger fraction of modules (about 1/2 of the full detector) participated in the February/March 2008 data taking. The installation of services was completed in May 2008. The SPD FastOR was integrated in the Central Trigger Processor and since May 2008 it was used to collect cosmic data in self-triggering mode as well as to provide the trigger to other detectors. A data sample of more than 100k SPD-triggered atmospheric muons for first track-based alignment of the ITS sensors and charge signal calibration in SDD and SSD was collected in summer 2008. The FastOR trigger for cosmic rays was given by a coincidence between the top and bottom half-barrels of the outer SPD layer and provided a trigger rate of ≈ 0.18 Hz. The ITS standalone tracker [2] was adapted to reconstruct the atmospheric muons as two back-to-back tracks starting from a fake vertex along the muon trajectory built from the points of the two SPD layers. A large number of sub-detector (SPD, SDD and SSD) specific calibration runs have also been collected to monitor the stability of the detector performance during 3 months of continuous operation.

2.1. Detector calibration and operation

SPD. The detector performance was optimized tuning several 8-bit DACs integrated in the front-end electronics and taking dedicated calibration runs to verify the pixel response. The calibration procedure is fully integrated in the ALICE calibration framework. It is based on detector algorithms which determine the proper values of the DACs by analyzing data from dedicated runs using either the on chip test-pulse or particles crossing the detector. In particular, for each of the 1200 front-end chips the pixel-matrix response and the minimum threshold have been optimized in order to maximize the efficiency and minimize the number of noisy pixels. A typical threshold value is about 2800 electrons. The remaining individual noisy pixels, corresponding to less than 0.15%, are masked and the information is stored in the Offline Conditions DataBase (OCDB) to be used in the offline reconstruction. The high power dissipation (1.32kW) mainly generated by the front-end chips requires an efficient cooling system to maintain an operating temperature around 30°C. The performance of the C₄F₁₀ based evaporative cooling has been studied in detail; the cause of few spots of lower efficiency, which prevented the full operation of some modules, has been found and corrective action has been taken. Before the winter shutdown, 212 modules out of 240 could be stably operated for data taking and trigger purpose. The SPD was operational during the LHC beam injection tests since June 2008 and provided relevant information to study the level of background induced in ALICE by the LHC monitoring equipments.

SDD. 246 out of 260 SDD modules were included in DAQ during summer 2008. The SDD calibration strategy is based on three types of standalone runs collected periodically during the data taking and analyzed by dedicated quasi-online algorithms that store the obtained calibration parameters in the OCDB. The first type is the pedestal run which allows to measure for each of the 133k anodes the values of baseline and noise as well as to tag the noisy channels ($\approx 0.5\%$). The baselines are then equalized to a common value in the front-end analog memory buffers [3]. In the pulser runs, a test pulse is sent to the pre-amplifiers to measure the gain and to tag the dead channels ($\approx 1\%$). Finally, injector runs provide a measurement of the drift speed in 33 positions along the anode coordinate for each SDD module by exploiting the MOS charge injectors integrated on the detector surface [4]. This is a crucial element for the detector calibration since the drift speed depends on temperature (as $T^{-2.4}$) and it is therefore sensitive to temperature gradients in the SDD volumes and to temperature variations with time. A correction for non-uniformity of the drift field (due to non-linearities in the voltage divider and for few modules also to significant inhomogeneities in dopant concentration) is applied: it is extracted from measurements of the systematic deviations between charge injection position and reconstructed coordinates that was performed on all the 260 SDD modules with an infrared laser [5].

SSD. 1477 out of 1698 SSD modules took data in summer 2008. The fraction of bad strips was $\approx 1.5\%$. Most of the modules not included in the data taking were drawing unexpectedly high bias current and were switched off as a precaution, pending further investigation, although their performance was good. The SSD gain calibration has two components: overall calibration of ADC values to energy loss and relative calibration of the P and N sides. This charge matching is a strong point of double sided silicon sensors and helps to remove fake clusters. Both calibrations relied on cosmics. The calibration constants were determined already in the laboratory, using cosmics on a spare ladder. This was refined during the cosmics runs with the SPD FastOR trigger. The resulting normalized difference in P- and N-charge has a FWHM of 11%. The absolute calibration matches within 5% with the standard values for energy loss from the literature.

2.2. Alignment with atmospheric muons

A good knowledge of the real detector geometry is a key point to obtain the design tracking performance of the ITS. The displacements and deformations of the ITS modules should be reconstructed from dedicated samples of tracks (from both cosmic ray and p-p events) with a precision sufficient to limit the worsening of resolution due to misalignment at no more than 20% of the nominal value. This is a challenging task having in mind that the total number of degrees of freedom is greater than 13000 and that for SPDs the nominal resolution on $r\phi$ coordinate is $12\ \mu\text{m}$. The relative position of ITS and TPC has also to be extracted with track-based methods and it is monitored by an optical alignment system with an accuracy better than $20\ \mu\text{m}$ [6]. The starting point for the ITS internal alignment procedure are the optical measurements (survey) performed during the construction phase. Then, track-based methods are applied following a hierarchical sequence which, for each sub-detector barrel (SPD, SDD and SSD), starts from assemblies of sensitive elements mounted on common mechanical supports and moves at each step to smaller and smaller structures down to the level of single modules. Two distinct methods based on the minimization of the residuals between tracks and reconstructed points are used, namely the Millepede [7] and a module-by-module iterative approach. The results obtained with the iterative method are of similar quality as the Millepede ones. A comparison of the extracted alignment parameters with the two methods can be used to assess the systematics.

After running the alignment tools, three main observables are used to check the quality of the obtained results. First, track-to-point residuals are checked. An example is shown in fig. 1-left where the distances in $r\phi$ between the track fitted on the outer SSD layer and the points measured in the inner SSD layer are used to test the effect of the application of the SSD survey. The second tool sensitive to alignment quality is the comparison of track segment parameters (inclination and position) after splitting a muon track into two track segments crossing the top and bottom half-barrels respectively. As an example, in the middle panel of fig. 1 the distribution of the distance in the transverse plane (Δxy) for track segments reconstructed in the top and

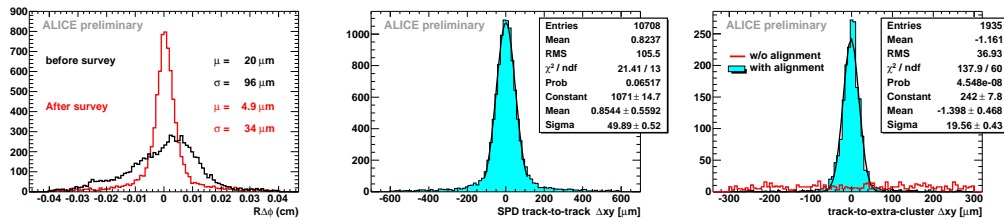


Figure 1: Left: track-to-point residuals in SSD with and without information from survey. Center: Track-to-track Δxy at $y=0$ after Millepede re-alignment. Right: Track-to-extra-cluster Δxy before and after re-alignment.

bottom part of SPD layers and propagated to $y=0$ is reported. It can be seen that after Millepede re-alignment a Gaussian r.m.s. of residual distributions of $50\mu\text{m}$ is obtained, which should be compared with the $40\mu\text{m}$ that are obtained from detailed Monte Carlo simulations of the ALICE apparatus with ideal geometry. Finally, the third used observable is the distance between clusters in the region where there is an acceptance overlap between two adjacent modules (extra-clusters). A particle passing through these overlapping regions produces two points very close in space whose reconstructed distance is sensitive to the relative misalignment of the two modules. In fig. 1-right the track-to-point distance for the SPD extra-clusters in the $r\varphi$ plane before and after Millepede re-alignment is displayed. From the width of the distribution, one can estimate the spatial resolution on the single SPD point as $\sigma_{\text{spatial}} \approx \sigma_{\Delta xy} / \sqrt{2} \approx 14\mu\text{m}$, which has to be compared with the $11\mu\text{m}$ that are obtained from simulations with ideal geometry. The alignment of SDD detectors for the $r\varphi$ coordinate (reconstructed from the drift time) is complicated by the interplay between the geometrical misalignment and the calibration of drift speed and t_0 (i.e. the measured drift time for particles with zero drift distance). The t_0 can be extracted either from the minimum measured drift time or from the track-to-point residual distributions along the drift direction. These distributions, in case of mis-calibrated t_0 , show two opposite-signed peaks due to the presence, in each module, of two separated drift regions where electrons move in opposite directions. After a first calibration with these methods, a refinement is obtained by adding in the Millepede the t_0 as a free global parameter for each of the 260 SDD modules. Similarly, the drift speed has been added as a free parameter for those SDD modules with mal-functioning injectors.

2.3. Charge calibration with atmospheric muons

The atmospheric muons provide also a sample of ionizing particles for absolute calibration of the dE/dx (from ADC units to keV) for SDD and SSD. In case of SDD detectors, the collected charge actually depends on drift distance due to the applied zero-suppression: the larger the drift distance, the larger the charge diffusion and consequently the charge cluster develops wider tails which get more easily cut by the zero-suppression algorithm. The data sample of atmospheric muons allowed to validate the correction for this effect extracted from detailed simulations of the detector response. The correction for track inclination has also been tested and, for a small sample of tracks collected with magnetic field, a comparison of the SSD signals with the Bethe-Bloch expectation values has been done. All these checks are also important to validate the detector responses implemented in the simulations and used in the particle identification algorithms.

3. Conclusions

A successful data taking for commissioning the ALICE ITS has been carried out in summer 2008 with SPD-triggered atmospheric muons. It allowed to obtain a good knowledge of the calibration parameters for all the detectors and a first alignment for 85% of SPD and 50% of SSD modules. The ITS results to be well performing and ready for p-p and Pb-Pb collisions.

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